

IN THE CLAIMS:

Claims 1-6 (canceled).

Claim 7 (new): A Code Division Multiple Access (CDMA) communication system, characterized in that said system comprises:

user transmitters each comprising:

means for producing a composite set of Zero Cross Correlation Zone (ZCCZ) spreading sequences which are made by making a product code of semi-orthogonal sequences with Zero Correlation Zone (ZCZ) sequences, and have a property such that periodic cross correlation function between an arbitrary pair of said ZCCZ sequences for such a shift condition that said pair of spreading sequences may take cyclically shifted positions within a relative shift difference range in chip around the zero shift takes a value of zero, as mutually different spreading sequences for identifying data symbols coming from respective user stations,

means for selecting both one sequence and its polarity indicating one of binary values, out of N_M pieces of ZCCZ sequences which are in advance allocated to a user as a set of spreading sequences so as to convey plural bits of transmission data per transmit-data symbol using a multi-ary modulation method,

means for producing an expanded symbol which is made by adding guard sequences to both sides of said selected ZCCZ spreading sequence with said selected polarity that is the central frame as a transmit base-band multi-ary data symbol,

means for transmitting said transmit base-band multi-ary data symbol, and
base station receivers each comprising:

means for receiving a received base band data symbol in which respective components corresponding to multi-ary data symbols having been sent out by user transmitters are multiplexed, and

means for despreading said received base band data symbol in correlation with N_M pieces of said local ZCCZ spreading sequences respectively which are allocated to a desired user station chosen for detecting its transmitted data out of all the user stations in said system to generate soft outputs, and

means for further deciding the most probable one of said N_M local ZCCZ sequences with its most probable polarity as an element signal included in said base-band data

symbol sent from said desired user station using such a maximum likelihood detection technique that a distance between said soft output and reference values takes the minimum among distances between said N_M soft outputs and said reference values, and thereby making hard decision to provide a detected data with plural bits which said desired user has transmitted.

Claim 8 (new): A Code Division Multiple Access (CDMA) communication system according to claim 7, characterized in that,

each user station belonging to said communication system comprises:

means for transmitting a data symbol as well as a pilot sequence as an isolated pilot frame from a user transmitter of said user station to a receiver of a base station via an up-link transmission of said communication system,

said base station receiver comprises:

means for producing respective pilot responses for said up-link transmission using cross correlation functions between respective received pilot sequences incoming from all of said user transmitters and an arbitrary spreading sequence or an analyzing sequences orthogonal to respective said pilot sequences, and

mean for storing a pilot response matrix consisting of said pilot responses, and

means for producing soft outputs by analyzing a received base band data symbol with said pilot response matrix,

said base-station transmitter comprises:

means for transmitting a data symbol as well as a pilot sequence as an isolated pilot frame to all of the user receivers via a down-link transmission of said communication system, and

each of said user receiver comprises:

means for producing respective received pilot responses for said down link transmission using cross correlation functions between received pilot sequences incoming from said base station transmitter and, an arbitrary spreading sequence or an auto-orthogonal sequence and

means for producing soft outputs by analyzing received base-band data symbol with said pilot response matrix for said down-link transmission.

Claim 9 (new): A Code Division Multiple Access (CDMA) communication system

utilizing a composite set of Zero Cross Correlation Zone spreading sequence (ZCCZ) characterized in that said system comprises:

means for producing said composite set of ZCCZ spreading sequences using techniques comprising:

means for producing a set of K sequences named by the k -th ($k=1, 2, \dots, K$) sequence with length N_1 belonging to a Zero Correlation Zone (ZCZ) sequence family where the k -th sequence has a value of zero for a periodic auto-correlation in such a shift condition that one of a pair of said spreading sequences may take a cyclically shifted position within a shift range around the zero shift, and a periodic cross-correlation function between an arbitrary pair of sequences belonging to said ZCZ sequence family takes a value of zero in such a shift condition that one of said pair of spreading sequences may take a cyclically shifted position within a shift range around the zero shift, including the 0 shift,

means for producing a block sequence family d with sequence length N_2 that is prime to N_1 , which consists of P sets of semi-orthogonal sequences denoted by $(d_1, d_2, \dots, d_p, \dots, d_P)$, each is named where the p -th set of semi-orthogonal sequences d_p consists of J sequences denoted by $(d_{p1}, d_{p2}, \dots, d_{pp}, \dots, d_{pJ})$, each is named by the pj -th sequence, where Hamming distance between an arbitrary pair of sequences belonging to said block sequence family d takes a relatively large value,

means for producing a repetitive ZCZ sequence and a repetitive block sequence by repeating both the ZCZ and the block sequences N_1 and N_2 times respectively so that said repetitive ZCZ and said repetitive block sequences may take the same sequence length N that is N_1 times N_2 , and

means for producing in advance a set of KPJ product sequences with sequence length N by multiplying in chip wise respective said repetitive ZCZ sequences by respective said repetitive block sequences, as a composite set of ZCCZ spreading sequences S_{kp}^j composed of three layers denoted by said parameters k , p and j .

Claim 10 (new): A Code Division Multiple Access (CDMA) communication system according to claim 9, wherein said CDMA system is composed of N_C cells each of which includes a base station and N_u users who are belonging to a cell and concurrently and temporarily given communication services with a base station belonging to said cell using a multi-ary

modulation scheme with N_M spreading sequences is characterized in that said system comprises:

means for using $N_C N_U N_M$ spreading sequences chosen out of a comosit set of ZCCZ sequences $\{S_{KP}^j\}$ having three layers denoted by parameters $k(=1,2,\dots,K)$, $p(=1,2,\dots,P)$ and $j(1,2,\dots,J)$ whose total number amounts to KPJ ,

means of allocating said KPJ ZCCZ sequences to $N_C N_U$ user-stations for an up-link multi-ary transmission or N_C base-stations for a down-link multi-ary transmission under such a condition that $N_C N_U N_M$ equals KPJ where each of said three numbers, N_C , N_U and N_M is allowed to take an integer larger than one.

Claim 11 (new): A Code Division Multiple Access (CDMA) communication system according to claim 9 characterized in that

as a set of J block sequences with length N_2 for a case of $P=1$, respective raw of a modified Hadamard matrix with a size $N_H \times (N_H-1)$ which is made by deleting the first column of an Hadamard matrix with a size $N_H \times N_H$ are used by setting N_2 as N_H-1 .

Claim 12 (new): A Code Division Multiple Access (CDMA) communication system according to claim 9 characterized in that

as a composite set of PJ block sequences with length N_2 being equal to N_H-1 layered by said parameters p and j , respective rows of a semi-orthogonal matrix with a size $N_H \times (N_H-1)$ which is made by deleting the first column of a deformed Hadamard matrix H_p produced by multiplying an Hadamard matrix with a size $N_H \times N_H$ by such a diagonal matrix S_p that the diagonal entries are the components of the p -th sequence s_p with length N_H belonging to a set of P low correlation sequences denoted by $(s_1, s_2, \dots, s_p, \dots, s_P)$ where a pair of said low correlation sequences have a large Humming distance are used.

Claim 13 (new): A Code Division Multiple Access (CDMA) communication system according to claim 9 characterized in that

one layer of said composite set of ZCCZ sequences $\{S_{KP}^j\}$ having three layers denoted by k , p and j is allocated to N_C cells to discriminate respective said cells, and said layer operators as a scrambling code for transmission and as a descramble code for reception.